# Three-Dimensional Quantitative Modeling of Progradational Systems: Application to the Neogene Development of the New Jersey Margin

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## LONG-TERM GOAL

Our long-term goal is to determine how along-shelf versus cross-shelf sediment transport, deposition, and erosion are affected by variations in sediment supply, climate, and relative sea level fluctuations. By simulating the stratal architecture, stacking patterns and associated facies preserved on a number of continental margins (e.g., New Jersey and the Eel river margins), we will be able to examine how relative sea level changes, variations in sediment supply, physiography, and climate affect stratal architecture and facies distribution through time.

## OBJECTIVES

The objective of our research is to explore the initial and boundary condition implications of the across- and along-margin advective and diffusive equation, especially in terms of clinoform morphology and its temporal variation.

## APPROACH

We have been using recently completed seismic stratigraphic interpretations of the Neogene clinoform development of the New Jersey margin as first-order constraints for our three-dimensional modeling (e.g., Fulthorpe and Austin, 1998; Poulsen et al., 1998). The three-dimensional geometry of the Miocene sediment packages comprising the New Jersey margin record the relative roles of advection and diffusion for both across- and along-margin transport. In addition, our three-dimensional model allows us to determine how sensitive across- and along-margin transport are to relative sea level changes, variations in sediment supply, climate, and physiography.

## WORK COMPLETED

We have modified the three-dimensional modeling program to include along-margin advection.

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We have examined the three-dimensional margin architecture of the depositional sequences preserved along the New Jersey margin, specifically the systems tracts that form the sequences to determine their along-margin variability.

We have simulated the internal clinoform geometry and morphology of the systems tracts (e.g., highstand systems tract, lowstand systems tract) in three dimensions to determine how the ratio of across-margin to along-margin transport varies during a sea level cycle.

**RESULTS**

Recent analysis of the three-dimensional nature of the late Miocene lowstand depositional systems suggests that away from the sediment source region that the paleo-waterdepth increases and sand content decreases (Poulsen et al., 1998). Furthermore, the lowstand wedge in strike-parallel seismic lines forms a convex lobe of sediment that downlaps onto the underlying strata. Our model results predicts that during relative sea-level falls, the advective and diffusive transportation of sediment basinward tends to be significantly more efficient than any movement of sediment along the margin. The consequence of the across-margin versus along-margin transport is that the lowstand wedge forms a convex package along strike that downlaps onto the underlying strata (Driscoll and Karner, in press). Our model predicts that the clinoform geometry changes dramatically along strike away from the sediment source region. For example, oblique clinoforms develop near the source region and evolve into an onlapping sequence along strike. On the basis of stratal geometry and the technique of sequence stratigraphy, this deposit would be interpreted as two different sequences with very different connotations for their formation. Our model predictions are consistent with observations from multichannel seismic data along the New Jersey margin.

Poulsen et al (1998) conclude that the sequences and their component systems tracks show remarkable along-strike variability with the lowstand depocenter shifted along-strike from the overlying highstand depocenter. The highstand system tract has greater regional along-strike distribution than the underlying lowstand systems tract. Consequently depending on the selected transect across the margin, the amount of deposition during the lowstand or highstand might be under or overestimated. Our three-dimensional modeling predicts that when the clinoform rollover is spatially coincident with the shoreline position, the clinoform geometry changes dramatically along strike away from the sediment source region (Driscoll and Karner, in press). Such a scenario exists during the deposition of the lowstand wedge (e.g., Poulsen et al., 1998). We surmise that when the clinoform rollover and the shoreline position are separated (e.g., a subaqueous delta), the along-strike variability of the clinoform geometry diminishes because of the hydrodynamic forces operative across the shelf. Our model predictions for both the lowstand and highstand systems tracts are consistent with new observations from the New Jersey margin (Poulsen et al., 1998). Our continuing efforts will be to further constrain how the ratio of across-margin to along-margin transport varies during a sea level cycle by using the clinoform geometry to assess the importance of advection and diffusion.

The advective and diffusive terms in the model play an important role in controlling the geometry of the resultant clinoform. For example, for a slow increase in relative sea level as a function of time and a constant sediment input rate, high advection maintains the geometry of the clinoform whereas high diffusion reduces the clinoform slope. The observations that diffusion minimizes bathymetric curvature and advection tends to maintain curvature implies that the long-term or steady-state condition is one that approaches a ramp morphology. Consequently, margins initially characterized by a ramp configuration that eventually evolve into a margin with a pronounced shelf/slope break do so in

response to a bathymetric perturbation induced by tectonics, current erosion, or sediment supply (e.g., New Jersey and West African margins).

## IMPACT/APPLICATION

Our initial work has clearly demonstrated that if the process is implicitly three dimensional (e.g., Poulsen et al., 1998; Karner and Driscoll, 1997; Martinson and Helland-Hansen, 1995), then the two-dimensional simplification procedure will prohibit the proper understanding of the system. This is underscored by the failure of two-dimensional modeling schemes to predict/model a sequence boundary in response to a lowering of relative sea level. The critical philosophical step is in realizing that we must begin the problem of stacking patterns as a three-dimensional problem. Consequently, we now have identified the key processes we need to constrain in order to model stratigraphic sequence development.

## TRANSITIONS

An important application of our research is understanding that the importance of along-strike variability in stratal architecture varies throughout a sealevel cycle. Our model indicates that when the clinoform rollover is spatially coincident with the shoreline position, the clinoform geometry changes dramatically along strike away from the sediment source region. Conversely, when the clinoform rollover and the shoreline position are separated, the along-strike variability of the clinoform geometry diminishes. Consequently, it is important to determine how clinoforms develop in three dimensions and to ensure that our window of observation is sufficient to discern between local and regional variability.

## RELATED PROJECTS

The goals of this project interface with and complement the objectives of a number of ongoing and proposed research projects within the ONR STRATAFORM Initiative.

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